Jour. Agric. Res. China (中華農業研究) 41(2) : 132~139 (1992)

Growth and Reproduction of Maize (*Zea mays* L. cv. Tainung No. 1) Response to Soil Water Deficits. I. Changes of Growth when Stress and Recovery Occurring at the Vegetative Stage in the Controlled Environment[1]

Chwen-Ming Yang[2] and Wei-Min Hsiang[3]

Abstract : The growth of maize during soil water deficets and after water recovery in the vegetative stage was investigated for plants grown in pots under controlled -environment conditions. Soll water deticits were imposed by withholding water from daily irrigation and released by rewatering. It was found that plant height was significantly declined when soil water potential reached down to −2.5 bars, but it can be recovered in 4 weeks when water deficits were released at soil water potential as low as −10 bars. Reduced plant height in the recovered plants measured at tasseling was therefore caused by plant height reduction during the stress period, rather than on the recovery. Leaf length, rather than leaf width was decreased by water deficiency, the inhibition of which were determined by stress level and time of water recovery. Additionally, total leaf number of a plant was not affected while leaf emergence rate was changed by a short period of water deficit. At harvest, leaf weight was not varied among treated plants but both stalk and root weights were declined with decreasing soil moistures. Ear weight was also reduced in stressed plants. It was concluded that moderate soil water deficit in the vegetative stage of maize would manipulate growth pattern but may not interrupt plant from entering the reproductive phase with appropriate water recovery. However, plant growth and reproduction may be reduced by severe water deficits even full irrigation was applied after stress period.

Key words : growth, reproduction, maize, soil water deficit, recovery, vegetative stage

Introduction

It has been shown that growth of maize, as well as others, is quite sensitive to water deficits (Acevedo *et al.*, 1971; Boyer, 1970; Hsiao, 1973; Michelena and Boyer, 1982; Van

1. Contribution No. 1616 from Taiwan Agricultural Research Institute (TARI).
2. Agronomist, Department of Agronomy, TARI, Wufeng 413, Taichung, Taiwan, ROC.
3. Assistant soil scientist, Departmint of Agricultural Chemistry, TARI.

Volkenburgh and Boyer, 1985). Expansion of leaves, stems, and roots and ultimately the development of reproductive organs are reduced when water deficit imposed on the vegetative stage (Denmead and Shaw, 1960). However, relatively little research has been conducted to determine the differential responses of maize growth to the water recovery from the different water deficit levels.

A close relationship between growth rate and leaf water potential was found in some crops (Boyer, 1970; Ludlow and Ng, 1967; Michelena and Boyer, 1982). Van Volkenburgh and Boyer (1985) and Tanguilig *et al.* (1987) further demonstrated that the elongation of leaf is particularly susceptible in maize experiencing water deficit. Since leaf is the primary site of carbon source supply and photosynthate production, it imposes a strong influence on maize growth and yield (Sinclair, 1984; Watson, 1957). Nevertheless, whether leaf dimension, leaf number and leaf developmint are affected upon a short period of water deficit need to be clarified.

The objective of the present study was to identify differences in plant growth of maize resulted from various levels of short period of water deficit imposed on the vegetative stage. Changes of growth upon water recovery were also examined.

Mtaerials and Methods

Maize (*Zea mays* L. cv. Tainung No. 1) plants were grown in Wagner's pots (1/2000 a), one plant per pot, in a controlled-environment chamber with circulated ambient air, 12-h photoperiod, daytime irradiance of 650 u mole m^{-2} s^{-1} PAR (Cool-white fluorescent lamps: tungsten bulbs=1 : 3), 25°C constant temperature, and 72—78% RH. Plants were watered daily and water deficits were induced by withholding water until the defined levels, i.e., −2.5, −5.5 and −10 bars, and were rsleased by rewatering. The well-watered plants were used as the control. Time of stress treatments began when the ninth leaf was 50 to 60 cm long.

The soil was a mixture (1:9, dry weight basis) of vermiculite and silt loam, which contained 50.8% silt, 31.3% sand and 17.9% clay and with a pH of 5.5 and a saturated water content of 43.4%. The equivalent ot 150 kg of N/ha, 120 kg of P_2O_5/ha, and 90 kg of K_2O/ha was equally added to each pot in 5 times during maize lifespan. Soil water potential was measured daily at midday using gypsum blocks placed at 15 to 20 cm below the soil surface. Plant height and leaf dimension (length and width, measured at the widest portion of the leaf) were determined with a ruler. Days required for leaf emergence were also recorded.The experiment was designed as a complete randomized block with 5 replicates.

Results and Discussion

Water deficit is known to affect growth, development, dry matter partitioning and grain yield during any growth stage of maize (*Zea mays* L.). However, the magnitude of the growth impairment depends on the growth stage at the time of stress, the level and duration of water deficit, and the time of water recovery, In this report, results indicated that plant height, leaf dimension and leaf developmint of maize showed a great response to soil water deficit and recovery.

Increase of plant height of maize was significantly declined by soil water potential below −2.5 bars (Fig. 1).When soil water potenial lowered down to under −10 bars, plant elongation was suppressed. Plant height was greatly promoted after rewatering at soil water potential of −10 bars and up, and was recovered in 4 weeks (Fig. 1). The pattern of plant height reduction and the recovery rate depended on stress level and the time of water recovery. Reduced plant height in the recovered plants measured at tasseling was therefore caused by plant height reduction during the stress period, rather than on the recovering period (Fig. 1 and and Table 1).

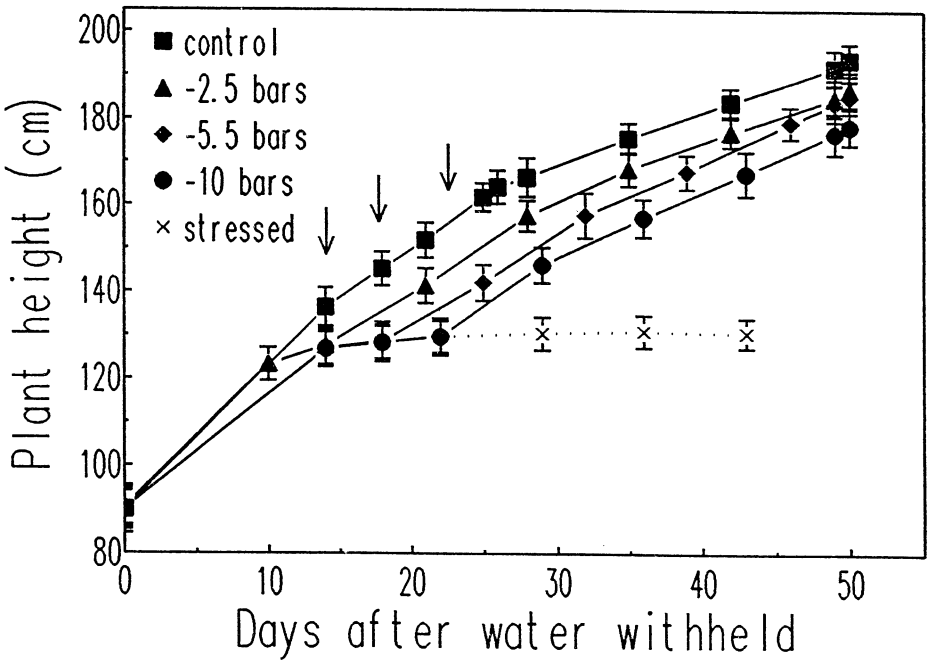

Figure 1. Changes of plant height of maize plants in response to soil water deficits and recoveries under controlled-environment conditions. Times of rewatering are marked in arrows and the standard deviation is included. The stressed plants received no irrigation after water withholding.

Table 1. Plant height and total leaf number at tasseling, and tasseling and silking dates of control and treated plants of maize, Tainung No. 1.

Item	control	−2.5 bars@	−5.5 bars	−10 bars
Plant teight (cm)	205.3	197.4	194.8	195.1
Total leaf no.	25	25	25	25
Tasseling date@@	Nov.26	Nov.29	Nov.29	Nov.28
Silking date	Dec. 2	Dec. 4	Dec. 1	Dec. 2

@ Soil water potential at which water deficit was released.
@@Planting date : Aug. 18, 1991.

There was a decreasing trend in leaf length, but not leaf width, with decreasing soil water potentials (Figs. 2 and 3), which was no surprise since the process of leaf expansion is known to be influenced by even small water deficits (Boyer, 1968, 1970; Bunce, 1977; Hsiao, 1973). This experiment further found that reduction of leaf length by a short period of water deficit can prolong to a certain duration, occurred from Leaf 8 extended up to Leaf 14 in this case, even upon rewatering. Thus, total leaf area was greatly decreased through reduced leaf expansion and increased senescence rate (Bennett and Hammond, 1983; wilson and Allison, 1978).

Tugor maintenance and proton excretion to the apoplastic space in the wall-loosening processes are the two major factors often documented in the literature governing cell enlargement (Cleland and Rayle, 1978; Dwyer and Stewart, 1985; Haiao, 1973; Tanguilig *et al.*, 1987; Van volkenburgh and Cleland, 1980). Van Volkenburgh and Boyer (1985) further pointed out that the cause of the inhibition effect of lower water potential on maize growth was to impair the ability of growing cells to excret protons acidifying the cell wall space, which related to the regulation of cell enlargement. Meyer and Boyer(1972)and Michelena

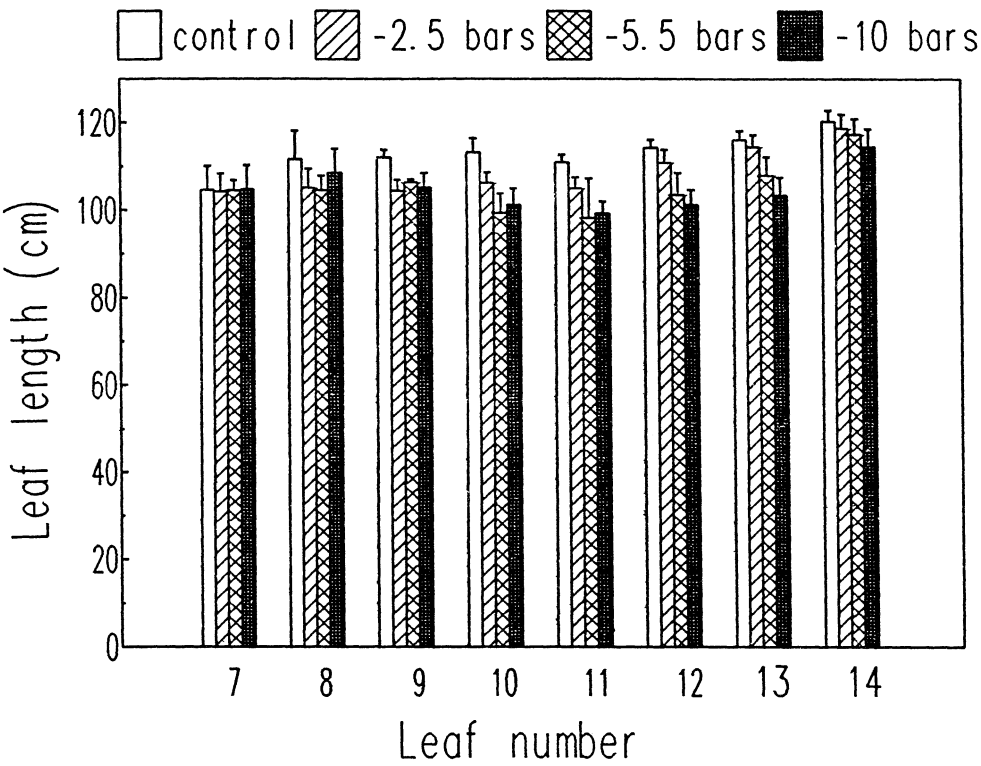

Figure 2. Comparison of leaf lengths of control and the recovered plants of maize, Tainung No. 1.

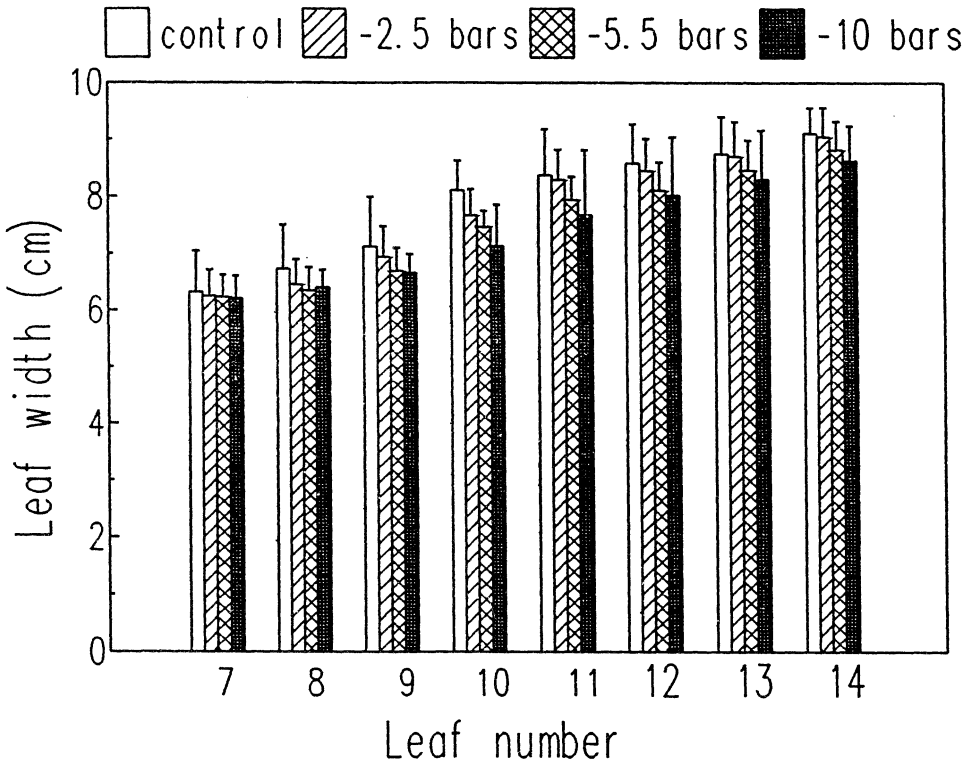

Figure 3. Comparison of leaf widths of control and the recovered plants of maize, Tainung No. 1.

and Boyer (1982) mentioned that growth of soybean and maize often is inhibited even though trugor maintenance is obtained, especially in stem and leaf tissue. In addition, the broken of the physiological balance by water deficit would further inhibit maize growth since many mechanisms such as carbon metabolism, transpiration and nutrient uptake were restrained (Begg and Turner, 1976; Hsiao, 1973; Levitt, 1980; Sullivan and Eastin, 1974; Tanguilig *et al.*, 1987; Turner and Kramer, 1980).

The rate of leaf emergence was interfered by water stress treatments (Table 2), but the total leaf number per plant measured at tasseling was not changed (Table 1). The result was in contrast to those reported by others (Bennett and Hammond, 1983; Wright and Keener, 1982), which may due to the variations of the experimental conditions. It was indicated that the dates of tasseling and silking were not influenced by water deficits (Table 1). Apparently, maize development, in terms of the times of tasseling and silking, was not retarded by moderate water deficit occurred during the vegetative stage if water recovery was applied in time.

Table 2. Comparison of days required for leaf emergence of control and the treated plants of maize, Tainung No. 1.

Leaf no	Control	−2.5 bars @	−5.5 bars	−10 bars
10	3	3	3	3
11	5	4	5	4
12	6	7	8	8
13	10	11	23	23
14	15	20	26	26
15	28	22	28	27
16	26	29	33	32

@Soil water potential at which water deticit was released.

Dry weights of the different plant parts at harvest were shown in Fig. 4. Leaf weight was not varied among treated plants while both stalk and root weights were declined with decreasing soil moistrues. Ear weight was also reduced in stressed plants. A 13% difference in plant weight was found between control and the stressed plant received −10 bars of soil water potential treatment. Similar results were reported by Denmead and Shaw (1960), in which the vegetative and the reproductive organs were reduced when water deficit imposed on the vegetative stage.

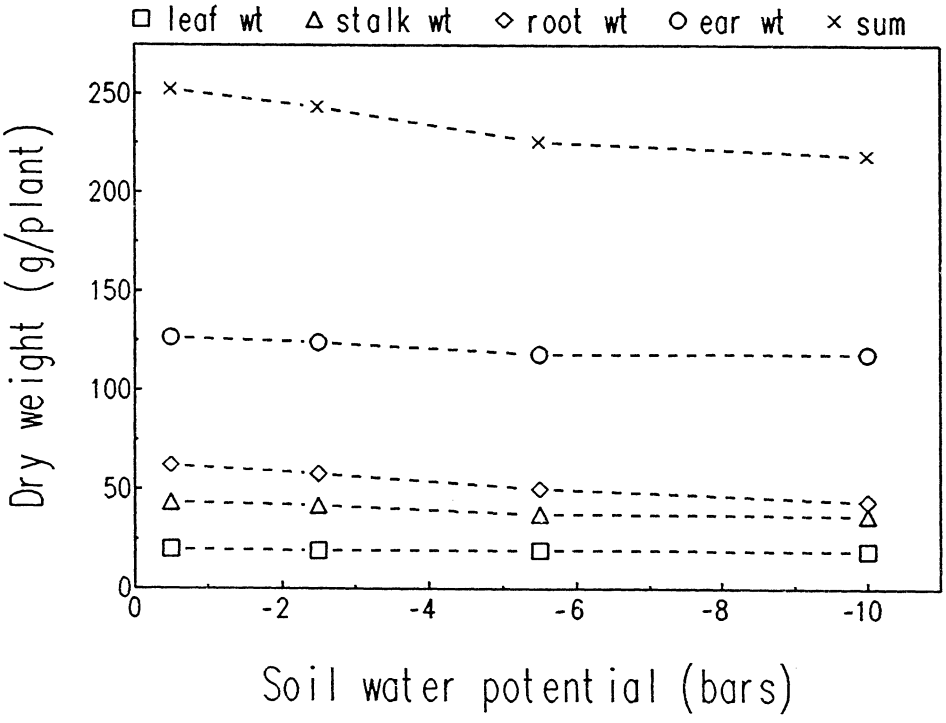

Figure 4. Dry weights of the different plant parts of maize, Tainung No. 1, at harvest as a function of soil water potential.

It is therefore concluded that short-term moderate soil water deficit occurs in the vegetative stage of maize would manipulate growth pattern but may not interrupt plant from entering the reproductive phase with appropriate water recovery. However, plant growth and reporduction may be reduced in severe water stress even full irrigation was applied after stress period.

References

Acevedo, E., T.C. Hsiao, and D.W. Henderson. 1971. Immediate and subsequent growth response of maize leaves to changes in water status. *Plant Physiol.* 48 : 631-636

Begg, J.E., and N.C. Turner. 1976. Crop water deficits. *Adv. Agron.* 28 : 161-217.

Bennett, J.M., and L.C. Hammond. 1983. Grain yields of several corn hybrids in response to water stresses imposed during vegetative growth stages. *Proc. Soil Crop Scl. Soc. Fla.* 24 : 107-111.

Boyer, J.S. 1968. Relationship of water potential to growth of leaves. *Plant Physiol.* 43 : 1056-1062.

Boyer, J.S. 1970. Leaf enlargement and metabolic rate in corn, soybean, and sunflower at various water potentials. *Plant Physiol.* 46 : 233-235.

Cleland, R.E., and D.L. Rayle. 1978. Auxin, H^+-excretion and cell elongation. *Bot. Hag. Tokyo Spec.* Issue 1 : 125-139.

Denmead, O.T., and R.H. Shaw. 1960. The effects of soil moisture stress at different stages on development and yield of corn. *Agron. J.* 52 : 272-274.

Dwyer, L.M., and D.W. Stewart. 1985. Water stress conditioning of corn (*Zea mays*) in the field and the greenhouse. *Can. J. Bot.* 63 : 704-710.

Hsiao, T.C. 1973. Plant responses to water stress. Ann. Rev. *Plant Physiol.* 24 : 519-570.

Levitt, J. 1980. Responses of plants to environmental stresses. 2nd ed. Vol. II. Water, radiation, salt and other stresses. p.25-280. Academic Press, N.Y.

Ludlow, M.M., and T.T. Ng. 1967. Leaf elongation rate in *Panicum maximum* var. trichoglume removal of water stress. *Aust. J. Plant Physiol.* 4 : 263-272.

Meyer, R. F., and J. S. Boyer. 1972. Sensitivity of cell elongation to low water potential in soybean hypocotyls. *Planta* 108 : 77-87.

Michelena, V.A., nd J.S. Boyer. 1982. Complete trugor maintenance at low water potential in the elongating region of maize leaves. *Plant Physiol.* 69 : 145-1149.

Sullivan, C.Y., and J.D. Eastin. 1974. Plant physiological responses to water stress. *Agric. Meteorol.* 14 : 113 -127.

Tanguilig, V.C., E.B. Yambao, J.C. O'Toole, and S.K. De Datta. 1987. Water stress effects on leaf elongation, leaf water potential, transpiration, and nutrient uptake of rice, maize, and soybean. *Plant Soil* 103 : 155-168.

Turner, N.C., and P.J. Kramer. 1980. Adaptation of plants to Water and high temperature stress. p. 482. Wiley Interscience, N.Y.

Van Volkenburgh, E., and K.E. Cleland. 1981. Proton excretion and cell expansion in bean leaves. *Planta* 148 : 272-278.

Van Volkenburgh, E., and J.S. Boyer, 1985. Inhibitory effects of water deficit on maize leaf elongation. *Plant Physiol.* 77 : 190-194.

Wright, A.D., and M.E. Keener. 1982. A test of a maize growth and developmint model, CORNF. *Agric. Systems* 9 : 181-197.

玉米 (*Zea mays* L. cv. Tainung No. 1) 生長與產量對土壤缺水之反應 (一)營養生長期缺水及灌水恢復對生長之影響[1]

楊 純 明[2]　向 為 民[3]

摘要：本文試驗旨在探討控制環境下，營養生長期土壤缺水及灌水恢復對玉米生長之影響。土壤缺水及灌水恢復係以灌水與否控制。根據試驗結果，當土壤水分潛勢下降至－2.5 bars 以下時，玉米植株之株高將明顯降低。在土壤缺水達 －10 bars 之前予以灌水恢復，株高伸長可在四星期內增加至與不缺水之對照組相當，故處理間在雄穗抽出時所測得株高之差異，乃肇因於缺水處理期間株高伸長降低，而非灌水恢復期間株高伸長遲緩引起。葉長亦受到缺水阻滯，其減少情形端視缺水程度及灌水恢復時間決定。玉米植株葉片數雖然不因土壤缺水影響，但葉片伸出率則發生變化，即葉片伸出所需時間隨缺水程度增加而延長。收穫時，處理葉片乾重雖無差異，莖稈重、根重、及穗重均因土壤缺水而減少。綜此試驗結果，本文認爲營養生長時期中等程度缺水將改變玉米生長模式，惟若能及時灌水恢復則不影響其進入生殖生長期。在嚴重缺水狀況下，玉米植株生長及產量將會受到顯著抑制。

關鍵詞：玉米、產量、生長、土壤缺水、灌水恢復、營養生長期

---

1. 臺灣省農業試驗所研究報告第 1616 號。
2. 臺灣省農業試驗所農藝系副研究員。臺灣省　臺中縣　霧峰鄉。
3. 臺灣省農業試驗所農化系助理研究員。